# Great Lakes Prey Fish Populations: A Cross-Basin Overview of Status and Trends from Bottom Trawl Surveys, 1978-2010[1]

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Assessment of prey fish stocks in the Great Lakes using bottom trawls have been conducted annually since the 1970s by the Great Lakes Science Center, sometimes assisted by partner agencies. Prey fish stock assessments differ among lakes in the proportion of a lake covered, seasonal timing, bottom trawl gear used, sampling design, and the manner in which the trawl is towed (across or along bottom contours). Because each assessment is unique in one or more important aspects, a direct comparison of prey fish catches among lakes is problematic. All of the assessments, however, produce indices of abundance or biomass that can be standardized to facilitate comparisons of trends among lakes and to illustrate present status of the populations. We present population indices for important prey fishes in the Great Lakes standardized to the highest value for a time series within each lake: cisco (*Coregonus artedi*), bloater (*C. hoyi*), rainbow smelt (*Osmerus mordax*), and alewife (*Alosa pseudoharengus*). We also provide indices for round goby (*Neogobius melanostomus*), an invasive fish presently spreading throughout the basin. Our intent is to provide a short, informal report emphasizing data presentation rather than synthesis; for this reason we avoid use of tables and the need to cite references.

Gear bias is always a concern when conducting fishery assessments. Bottom trawls are reliable tools for measuring relative abundance and biomass of fish living near the lake bottom. Inter-annual variation in the proportion of a fish population collected near the lake bottom will, of course, result in some measurement error. The types, sizes, and numbers of fish caught by the trawl are influenced by many variables, such as dimensions of the net and speed at which it is towed. Nonetheless, we believe that the information presented in this report is the best available long-term index of relative abundance for these fish in the Great Lakes. Our approach of indexing relative abundance estimates from bottom trawl catches to the maximum observed estimate in the time series is the only practical means of comparing relative trends across the Great Lakes and is relatively insensitive to differences in sampling design.

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To make statistical comparisons of trends among lakes, we restricted data to years when all or a group of lakes were sampled. For all lakes, data from 1992, 1993, 1998, and 2000 were omitted from comparisons because of missing or atypical data were collected in one or more lakes. Specifically, 1992 and 1993 were omitted because Lake Huron was sampled 1 month earlier than the rest of the time series, 1998 was omitted because the vessel speed was too fast in lakes Michigan and Huron, and 2000 was omitted because Lake Huron was not sampled. Comparisons with Lake Erie were restricted to 1990-2010, years when surveys with a consistent sample design were conducted. Beginning with our 2010 report, a complete series of catch data from Lake Huron was made available for comparison with other lakes because fishing power corrections to the Huron data were developed to account for the use of a larger bottom trawl to conduct surveys during 1992-2010. For each lake, standardized relative indices for biomass of age-1 and older fishes and numeric density of recruits were calculated as the observed value divided by the maximum value observed in the times series. To determine whether time series for a given species were statistically "concordant" across the basin, we calculated the Kendall coefficient of concordance ($W$), which can range from 0 (complete discordance or disagreement among trends) to 1 (complete concordance or agreement among trends). The $P$-value for $W$ provides the probability of agreement across the lakes. First, we present trends in relative biomass of age-1 and older prey fishes to show changes in populations within each lake. Then, we present standardized indices of numerical abundance of a single age-class to show changes in relative year-class strength within each lake. Indices of year-class strength reliably reflect the magnitude of the cohort size at subsequent ages. However, differences in survey timing across lakes results in adopting different methods for selecting the fish age-class that is used to index year-class strength for each species. For Lake Superior cisco, bloater, smelt, and Lake Michigan alewife, assessment of year- class strengths are based on aged fish, and for all other samples age-classes were assigned based on fish length cut-offs. Depending on the lake and species, year class strengths were assessed from density of age-0, age-1 fish, or age-3 fish, which necessitated using years 1977-2010 to include all species. Our intent with this report is to provide a cross-lakes view of population trends but not to propose reasons for those trends.

**Relative Biomass, Age-1 and Older Coregonids**

Across the three upper Great Lakes, biomass of age-1 and older coregonids (cisco, in Lake Superior and bloater in lakes Superior, Michigan, and Huron) was relatively high from the mid-1980s through the mid-1990s (Fig. 1). There was 74% concordance among all time series ($W = 0.74$; $P < 0.0001$). Following the peaks in the mid-1980s through the mid-1990s, coregonid biomass has remained at low levels in lakes Huron and Michigan but has fluctuated 10-20% of peak levels in Lake Superior. In 2009, cisco and bloater biomass dropped to near-zero in Superior, the lowest values since 1978. In 2010, biomass increased ~3% due to the appearance of a weak 2009 year class. In Michigan and Huron, bloater biomass increased from 1% of peak levels in 2008 to 3 and 19% in 2010, respectively. Bloater were absent from survey catches in lakes Erie and Ontario and cisco were rarely encountered in any lake other than Superior.

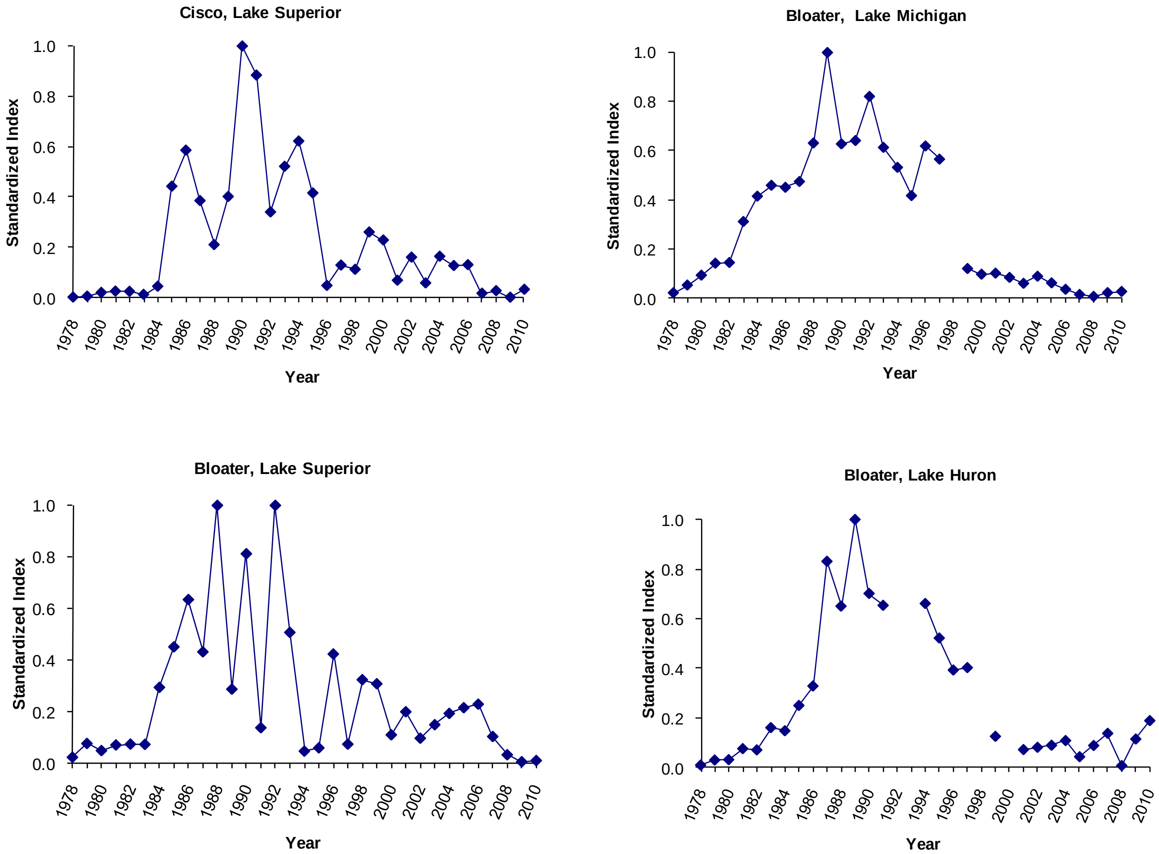


**Figure 1.** – Standardized indices of biomass for age-1 and older cisco in Lake Superior and for age-1 and older bloater in lakes Superior, Michigan, and Huron, 1978-2010. Missing data points in lakes Michigan and Huron are explained on page 2.

## Relative Biomass, Adult Alewife

Trends in relative biomass of adult alewife across lakes Michigan, Huron, and Ontario were variable, though biomass was higher early in the time series and lower in more recent years (Fig. 2). For all three lakes, there was moderate (59%) concordance among the time series ($W = 0.59$; $P < 0.01$). In Lake Michigan, relative biomass of adult alewife was high in the early 1980s and rapidly declined to lower levels in the mid-1980s that persisted through the 1990s. Subsequently, relative biomass of alewife in Lake Michigan rebounded strongly in 2002-2003 and then dropped to low levels in 2004-2010, achieving the lowest level in the time series in 2010. Similarly, relative biomass of alewife in Huron was high in the beginning of the time series, declined to low levels in the mid-1980s, but unlike Michigan, fluctuated widely in the late 1980s – mid 1990s with peaks in 1987 and 1994 and an intervening low in 1990-1991. After 1994, biomass declined to 18% of peak abundance in 1996, rebounded to 36% in 2002 and afterwards declined to near-zero levels in 2004-2010, achieving record lows in 2004, 2008, and 2009. In Lake Ontario, biomass of adult alewife was relatively high in the early 1980s but then gradually declined until 1996. During 1996-2005, biomass remained low except for a brief increase in 2000-2001 and then declined in 2006. In 2008-2009, biomass recovered to 35% of its peak abundance but in 2010 declined to a record low. Alewife is a rare species in Lake Superior and survey data for alewife in Lake Erie were not available for this comparison.

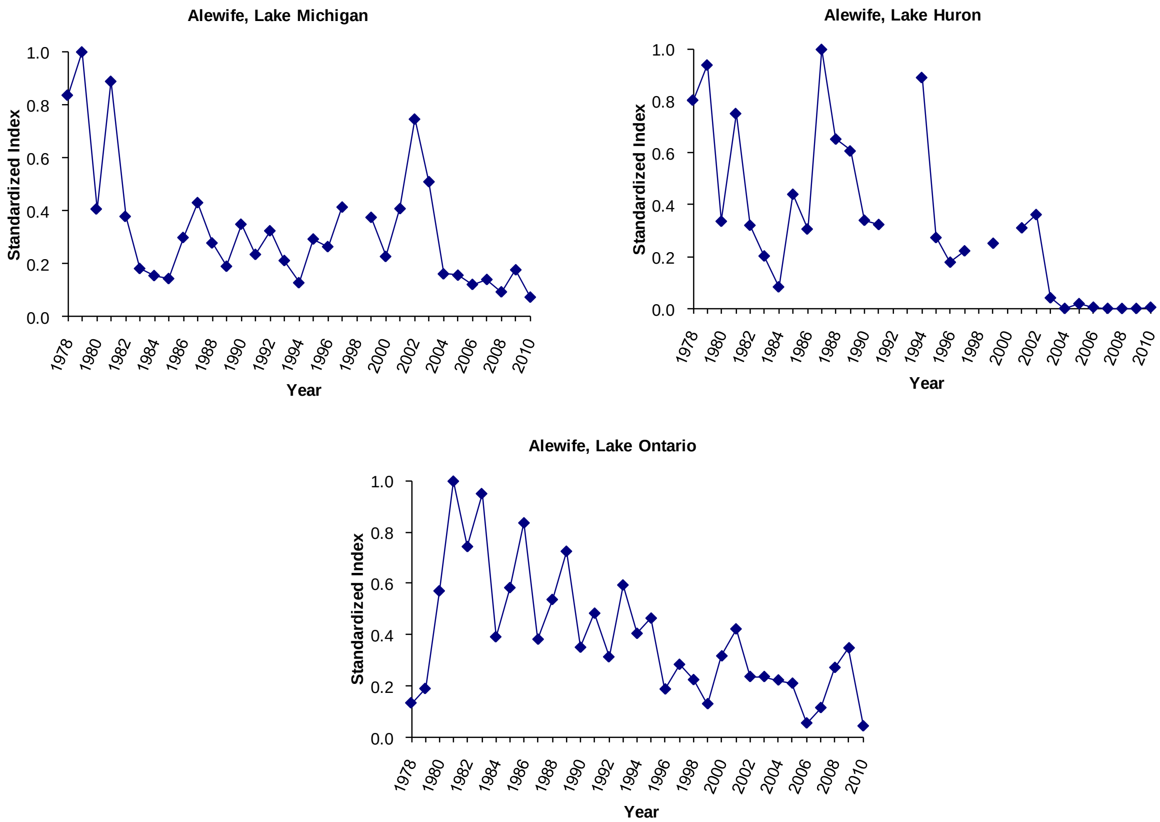


**Figure 2.** – Standardized indices of biomass for adult alewife in lakes Michigan, Huron, and Ontario, 1978-2010. Adult alewife are those fish that have completed two or more growing seasons; i.e. age 1 when surveys are conducted in fall (lakes Michigan and Huron) and age 2 when surveys are conducted in spring (Lake Ontario). Missing data points in lakes Michigan and Huron are explained on page 2.

## Relative Biomass, Age-1 and Older Rainbow Smelt

Lakes Superior, Michigan, Huron, and Ontario showed a common trend of fluctuating but declining relative biomass of age-1 and older rainbow smelt during 1978-2009 (Fig. 3; $W$ = 0.78; $P < 0.0001$). Relative biomass was at or near record lows in 2002-2004 in Lake Superior, increased to 13-16% of peak biomass in 2005-2007, declined to 7% in 2008, up to 11% in 2009, and down again to 7% in 2010. In similar fashion, relative biomass in Lake Michigan was near record lows during 2001-2003, rose nearly 4-fold in 2005, and then dropped to a record low of 1% of peak biomass in 2008 and increasing slightly in 2009-2010 to 3-4%. Mirroring the pattern in Michigan, relative biomass in Lake Huron declined to near-record lows in 2002-2003, increased to 13% of peak biomass in 2004 and then declined to record lows in 2008-2009, followed by a slight increase to 7% in 2010. A similar pattern was followed in Lake Ontario with near record low biomass in 2003, a small increase in 2004 and a decline to record low biomass in 2008 followed by a modest increase to 14% of peak biomass in 2010. Survey data for age-1 and older rainbow smelt in Lake Erie were not available for this comparison.

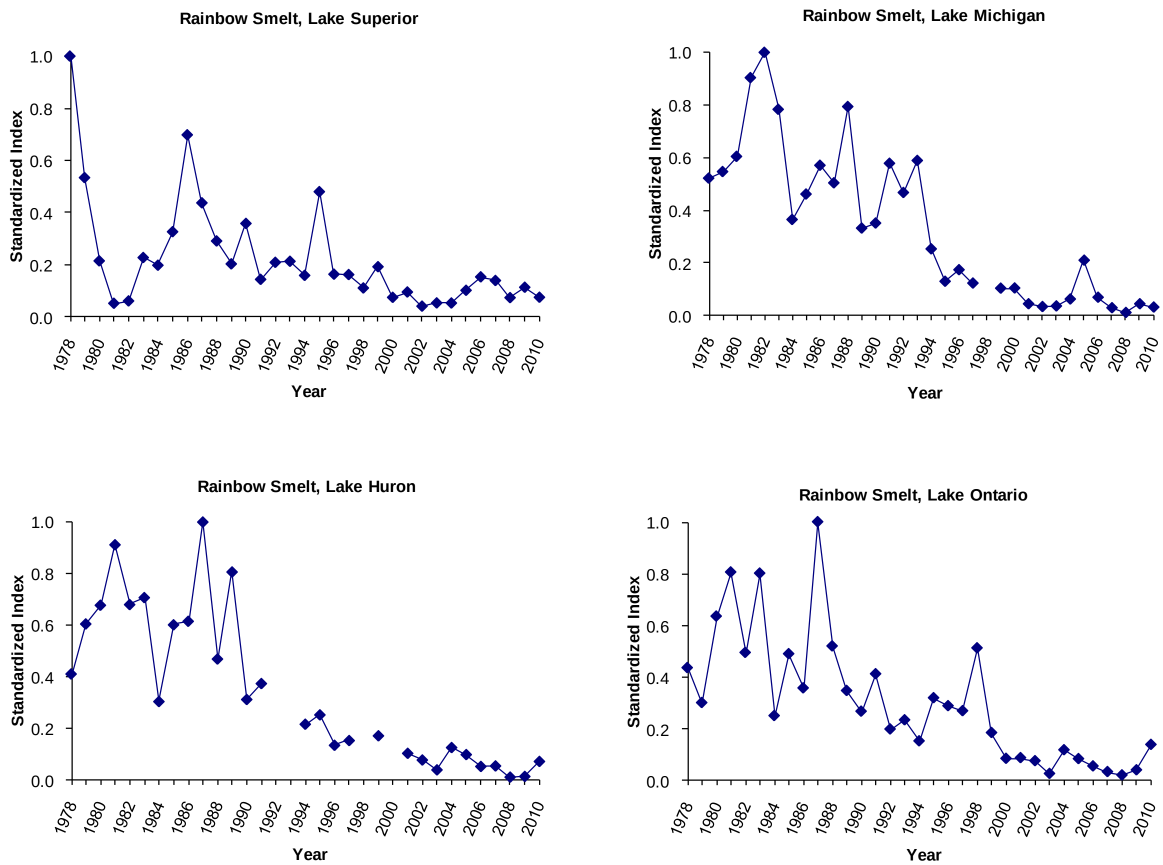


**Figure 3.** – Standardized indices of biomass for age-1 and older rainbow smelt in lakes Superior, Michigan, Huron, and Ontario, 1978-2010. Missing data points in lakes Michigan and Huron are explained on page 2.

## Year-Class Strengths, Coregonids

We observed moderate agreement in year-class strengths of coregonids ($W$ = 0.53; $P <$ 0.001) in lakes Superior, Michigan, and Huron (Fig. 4). All lakes shared a general pattern of stronger year-classes in the 1980s and weaker year-classes in subsequent years. Stronger concordance was not observed because of the appearance of recent strong year-classes in Lake Huron, with the strongest year-class appearing in 2007. Bloater were absent from survey catches in lakes Erie and Ontario and cisco are rarely encountered outside of Lake Superior.

## Year-Class Strengths, Alewife

There was no agreement ($W$ = 0.42; $P$ = 0.18) in alewife year-class strength among lakes Michigan, Huron, and Ontario for the 1977-2007 year-classes (Fig. 5). In all lakes, year-class strength was variable but at intermediate levels through the 1980s. Subsequently, lakes Michigan, Huron, and Ontario produced large year-classes in 1998; had this year-class been included in the statistical analysis, we may have found higher agreement across the basin. Lake Huron produced its strongest year-class in 2003, but was followed by negligible year-classes in 2004-2007. Alewife is a rare species in Lake Superior and survey data for alewife in Lake Erie were not available for this comparison.

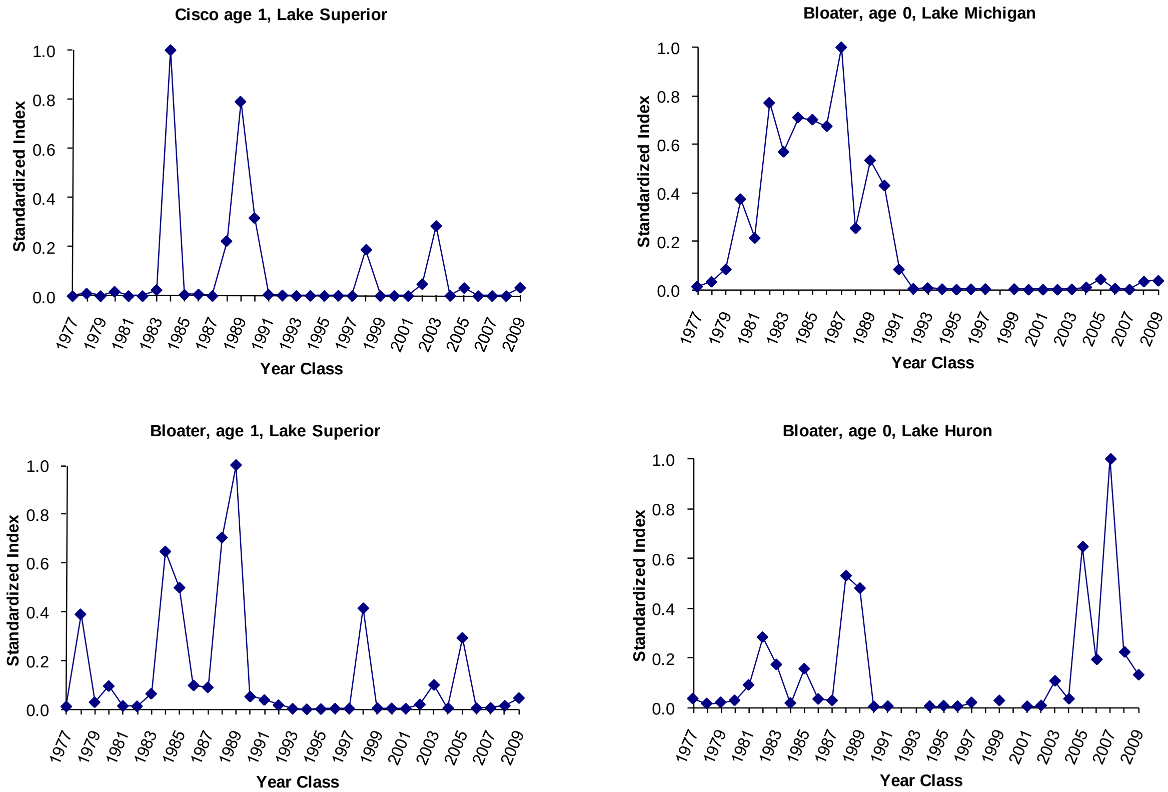


**Figure 4.** – Standardized indices of year-class strengths (age ≤1) for cisco and bloater in lakes Superior, Michigan, and Huron, 1977-2009. Missing data points in lakes Michigan and Huron are explained on p 2.

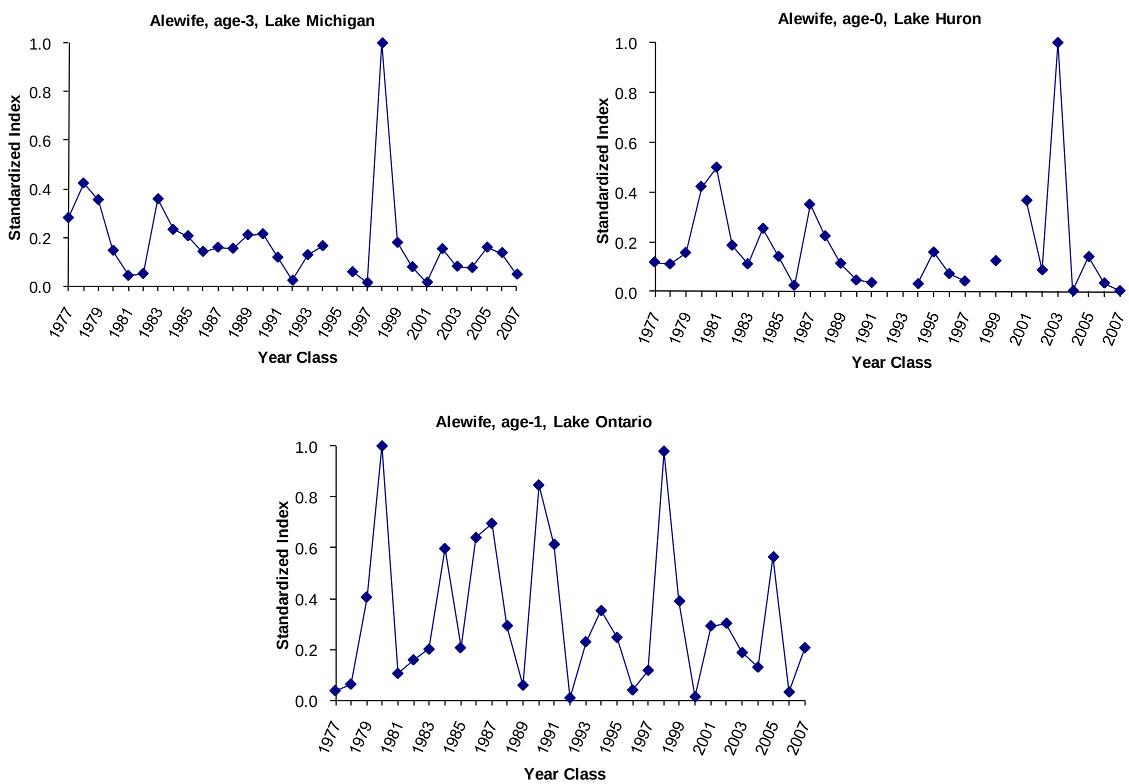


**Figure 5.** – Standardized indices of alewife year-class strengths measured at age 0, 1 or 3 (age of year-class strength is dependent on when alewife become fully vulnerable to survey on each lake) in lakes Michigan, Huron, and Ontario, 1977-2007. Missing data points in lakes Michigan and Huron are explained on page 2.

## Year-Class Strengths, Rainbow Smelt

No concordance was observed among rainbow smelt year-classes in lakes Superior, Michigan, Huron, and Ontario from 1977 to 2009 ($W$ = 0.34; $P$ = 0.10) (Fig. 6). In Lake Superior, year-class strengths varied from moderate to strong during 1977-1996, subsequently declined to weak levels in 1999-2002, and varied from weak to moderate in 2003-2009. In Lake Michigan, year-class strengths appear to have declined steadily from 1980 to 1997 and thereafter remained weak except for the moderately strong year classes in 2005 and 2008. In contrast to Michigan, year-class strengths in Huron were moderate to weak over the first 26 years of the 33-year time series, and then increased rapidly to a peak in 2005 followed by a steep decline with a record low in 2008. In Lake Ontario,

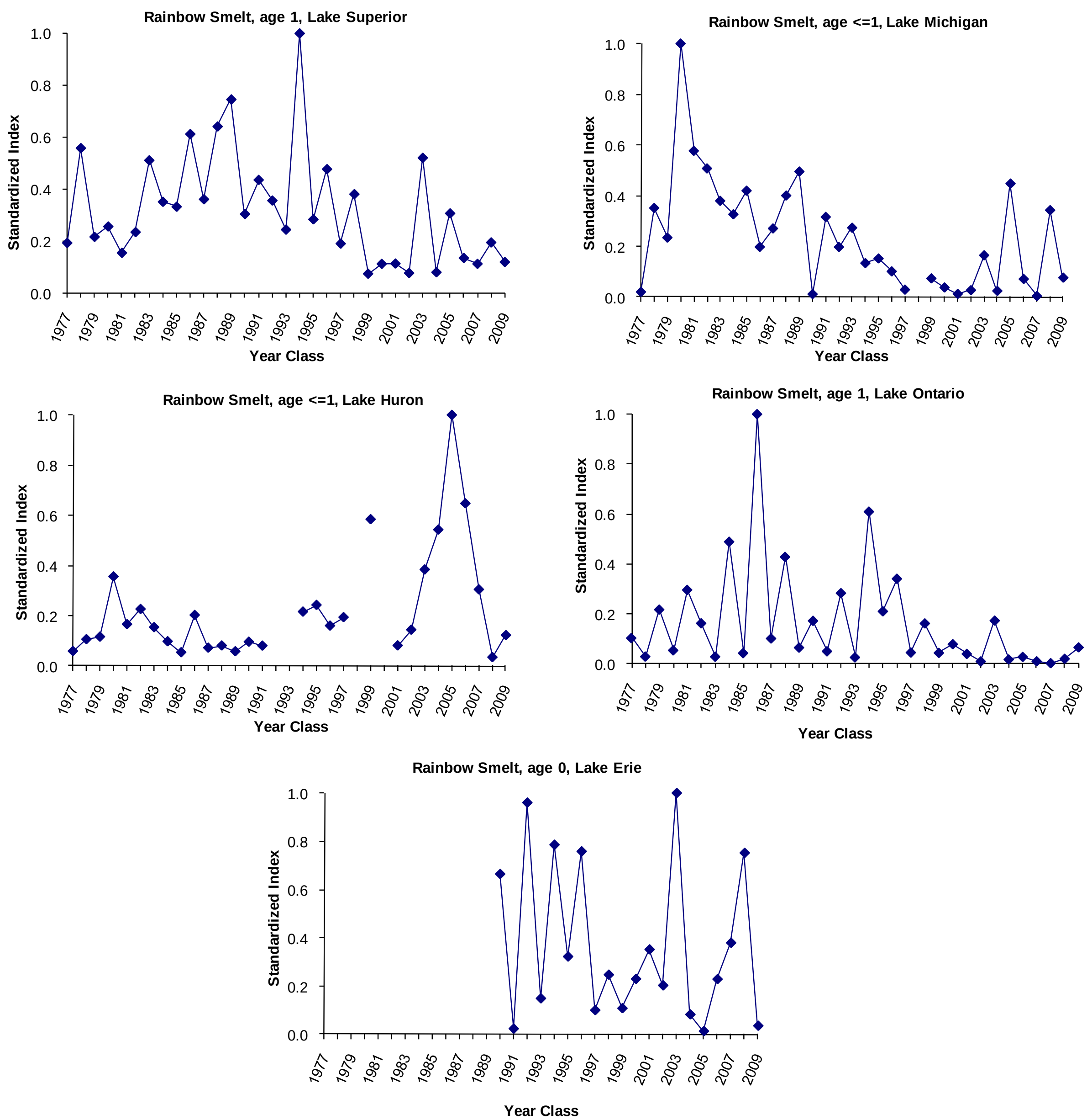


**Figure 6.** – Standardized indices of rainbow smelt year-class strengths measured at age 1, after the strength of the year-class is set in lakes Superior and Ontario and at age 0, after the strength of the year-class appears to be set in lakes Michigan and Huron, 1977-2009. Missing data points in lakes Michigan and Huron are explained on page 2.

prior to 1999, year-class strength showed a clear saw-tooth pattern caused by alternating strong and weak year-classes. This pattern was not discernible during 1999-2009 due to a succession of weak year classes. To include Lake Erie in our analysis, our comparison was restricted to the 1990-2009 year-classes. After including Lake Erie, agreement in trends in year-class strengths among all lakes increased ($W = 0.35$; $P < 0.04$). The 2009 year-class was relatively weak in all the lakes.

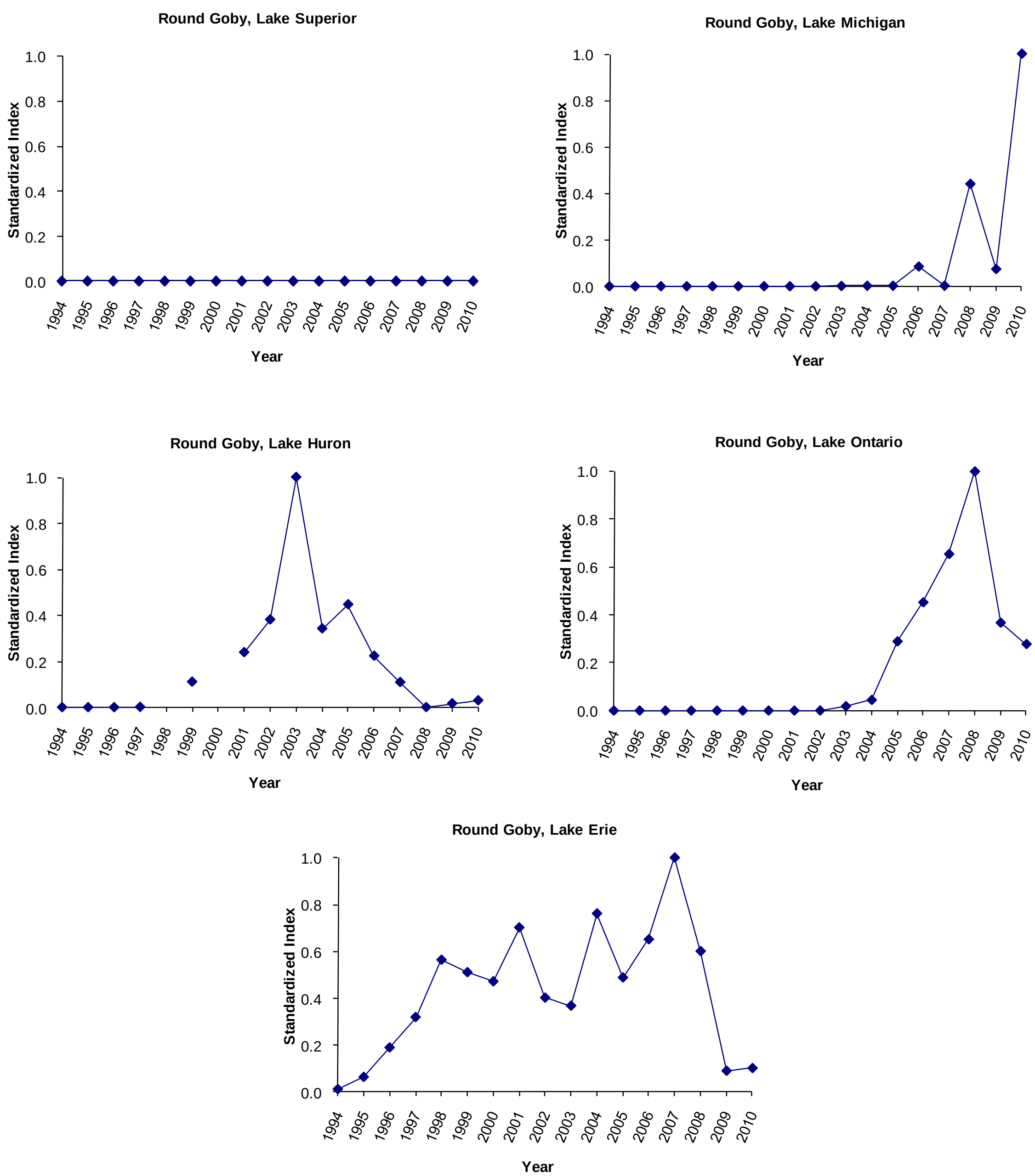


**Figure 7.** – Standardized indices of abundance for round goby in lakes Superior, Michigan, Huron, Erie, and Ontario, 1978-2010. Indices computed from number caught in Lake Erie and weight caught in all other lakes. Although a single round goby was caught in Lake Superior in 2005 near the entry to Duluth-Superior harbor, the catch was not made during the annual assessment and goby have not as yet been caught during that assessment. Missing data points in lakes Michigan and Huron are explained on page 2.

**Relative Abundance, Age-0 and older Round Goby**

Expansion of round goby populations in offshore waters varied among lakes, as judged from surveys in offshore waters, from complete in lakes Huron and Erie to pending in Lake Superior (Fig. 7). Moderate agreement in biomass trends ($W = 0.55$; $P < 0.007$) was observed among lakes where round goby has become established (Michigan, Huron, Erie, and Ontario). Greater agreement in trends among lakes was hindered by the desynchronized expansion of round goby populations, with the earliest occurring in Erie, followed by Huron and then by Ontario and Michigan. The peak biomass recorded in Michigan in 2010 indicates that goby populations are still expanding, though recent declines in the other lakes signals that those populations may be moving toward lower equilibrium levels.

**Summary**

We found basin-wide agreement in the trends of age-1 and older biomass for all species, with the highest concordance occurring for coregonids and rainbow smelt, and weaker concordance for alewife. For coregonids, the highest biomass occurred from the mid-1980s to the mid-1990s. Rainbow smelt biomass has declined slowly and erratically during the last quarter century. Alewife biomass was generally higher from the early 1980s through 1990s across the basin, but the patterns since the early 1990s have been divergent across lakes, though have trended downward in all lakes since 2005. In general, year-class strength patterns were less concordant across the basin. We found statistical agreement only for coregonids and the abbreviated (1990-2009) time series for rainbow smelt.

We found that biomass of age-1 and older coregonids, alewife, and rainbow smelt were at very low levels in 2010 compared to previous years in the time series. Low biomass levels in 2010 fit a trend of declining biomass of prey fish across the Great Lakes since 1990. The rapid expansion phase of round goby in lakes Huron, Erie and Ontario appears to be nearing completion, as indicated by sharp declines in biomass in 2009-2010, however, the record high 2010 biomass observed in Lake Michigan suggests that goby populations are still expanding there. There was an absence of round goby in spring bottom trawl assessments in Lake Superior, but their presence in the harbors and embayments of Duluth and Thunder Bay (U.S. Geological Survey and Ontario Ministry of Natural Resources, unpublished data), suggests that there is potential for future colonization.

**Acknowledgements**

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